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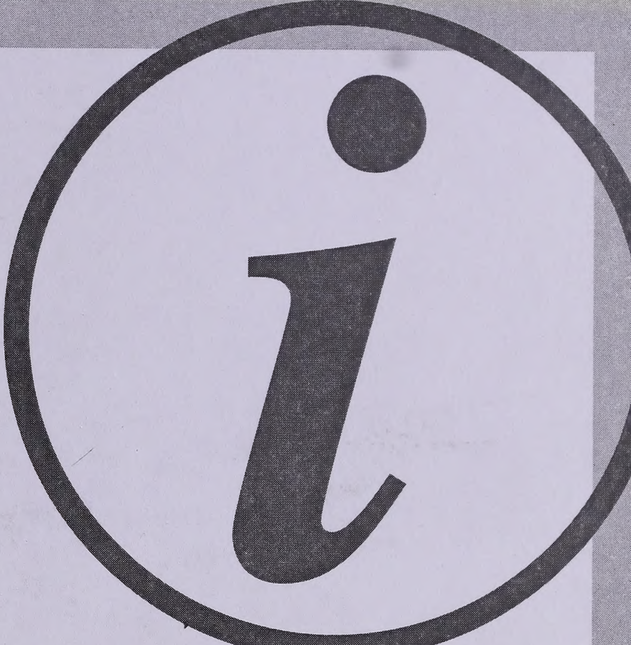
Chemistry 30



Information Bulletin

2001–2002 School Year

Diploma Examinations Program

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Contents

Page 1 *Objectives of the Course*

Page 1 *Performance Expectations*

Page 3 *Examination Specifications*

Page 3 *General Learner Expectations (GLEs)*

Page 5 *Examination Design*

Page 6 *Assessment of STS Connections*

NEW *Page 7* *Reminders and Explanations*

Page 12 *Assessment of Communication Skills*

Page 13 *Communication Scoring Guide for Closed-Response Questions*

Page 14 *New Generic Holistic Scoring Guide*

Page 19 *Sample Student Responses*

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Objectives of the Course

Chemistry 30 is intended to develop students' understanding of the interconnecting ideas and chemistry principles that transcend and unify the natural science disciplines and their relationship to the technology that students use in their daily lives. Chemistry 30 is an experimental discipline that develops the knowledge, skills, and attitudes to help students become capable of and committed to setting career and/or life goals, making informed choices, and acting in ways that will improve the level of scientific awareness essential for a scientifically literate society.

Students of Chemistry 30 are expected to develop an aptitude for observing, collecting data, forming generalizations, hypothesizing, and making inferences from observations. The course is designed to promote growth in students' understanding of chemical concepts, ability to apply these concepts to relevant situations, and ability to communicate in the specialized language of chemistry.

Success in Chemistry 30 requires the successful completion of Science 10 and Chemistry 20 and concurrent mathematics courses, which develop the requisite knowledge and skills.

Performance Expectations

Curriculum Standards

Provincial curriculum standards help to communicate how well students need to perform in order to be judged as having achieved the objectives specified in the *Chemistry 20–30 Program of Studies, 1998*. The specific statements of standards are written primarily to apprise Chemistry 30 teachers of the extent to which students must know the Chemistry 30 content and be able to demonstrate the required skills to be able to pass the examination.

Examples of Questions

In the archived information section on the web site, there are examples of questions that students should be able to answer in order to demonstrate the *acceptable standard* and the *standard of excellence*. The examples provided are by no means exhaustive; they are intended to provide a profile of acceptable and excellent achievement. They model the types of questions and problems that students should be able to solve and the types of activities that students should be able to perform in order to meet the specific outcome to which they are linked. Examples of questions from 1995 are included in the *Archived Information* of this bulletin on the web site.

Acceptable Standard

Students who meet the *acceptable standard* in Chemistry 30 will receive a final course mark of 50% or above. These students demonstrate a basic understanding of the nature of scientific investigation by designing, observing, and interpreting simple laboratory tests. They can readily interpret data that are presented in simple graphs and tables, and translate symbolic representations into word descriptions. They are able to recognize and provide definitions for key chemical terms and can predict the physical and chemical properties of compounds. They balance simple equations (combustion, formation, neutralization, or oxidation–reduction) and can solve standard, single-step, stoichiometric problems based upon these equations. Following laboratory procedures does not present a problem for these students, nor does using the data booklet to extract relevant information. These students compose clear and logical descriptive or explanatory statements to answer closed-response questions that involve individual chemistry concepts.

Standard of Excellence

Students who achieve the *standard of excellence* in Chemistry 30 receive a final course mark of 80% or higher. In addition to meeting the expectations for the *acceptable standard* of performance, these students demonstrate an interest in chemistry and can articulate chemistry concepts well. They can readily interpret interrelated sets of data such as complex graphs and tables. When presenting scientific data, they select the most appropriate and concise format. These students can analyze and evaluate experimental designs. They generate their own laboratory procedures when given a clearly defined problem, recognize weaknesses in laboratory work, and find ways to correct the weaknesses. They are able to formulate their own equations for formation, combustion, neutralization, redox reactions, and equilibrium expressions, and can solve many variations of stoichiometric problems based upon these equations. They transfer what they observe in a laboratory setting into equation form and express scientific ideas clearly. They solve problems that involve the overlapping of two or more concepts. The most significant characteristic of this group is that they solve problems of a new and unique nature and extrapolate these solutions to higher levels of understanding. Open-ended questions do not pose problems for them. These students communicate clearly and concisely, using appropriate scientific vocabulary and conventions.

Examination Specifications

Each Chemistry 30 diploma examination is designed to reflect the Chemistry 30 course general learner expectations outlined in the *Chemistry 20–30 Program of Studies, 1998*. Each examination is built as closely as possible to these specifications. Small adjustments in emphasis may be necessary because the examination includes multimark written-response questions and/or machine-scored questions that cover more than one concept area. The concept areas are distributed proportionately over the examination. Questions that require knowledge and skill in applying scientific processes are distributed throughout the examination but are not associated directly with specific topics; this is also true of the STS connections.

General Learner Expectations (GLEs)

		Emphasis (Curricular Fit)
GLE 1	Quantitatively Predicting Outcomes	30–40% (Units 1, 2, 3)
GLE 2	Qualitatively Analyzing Systems	60–70% (Units 1, 2, 3)
GLE 3	Relationships in Energy Transfer	28–32% (Unit 1)
GLE 4	Relationships in Electron Transfer	30–34% (Unit 2)
GLE 5	Relationships in Equilibrium Systems	16–22% (Unit 3)
GLE 6	Relationships in Proton Transfer	16–22% (Unit 3)

The 2001–02 Chemistry 30 diploma examinations are constructed to place the following approximate emphases on the Chemistry 30 course general learner expectations (GLEs).

Knowledge	***Emphasis***
The student can	100%
• apply conservation of matter and energy to changing systems; use evidence and knowledge to predict outcomes in a broad range of reactions	30%–40%
• analyze and evaluate physical, chemical, and biological systems in terms of forms, transfers, movement, and conservation of energy and matter	60%–70%
• explain the relationships in physical, chemical, and nuclear changes through the rearrangement of bonds and the resulting release or absorption of energy	28%–32%
• quantitatively and qualitatively explain and analyze the transfer of electrons and the associated transformations that take place in electrochemical systems	30%–34%
• quantitatively and qualitatively describe equilibrium systems for acids, bases, and gases and some of their applications	16%–22%
• quantitatively and qualitatively describe acids and bases in physical and conceptual terms using the Brønsted–Lowry theory	16%–22%

Scientific Process and Communication Skills (SPC)	***Emphasis***
The student can	40–60%
• design, interpret, explain, analyze, and evaluate investigations	
• organize data into tables, graphs, and diagrams, and predict relationships	
• interpret, explain, analyze, and evaluate data to infer relationships	
• use appropriate scientific terminology and mathematical language to communicate and explain scientific concepts	

Science, Technology, and Society Connection (STS)	***Emphasis***
The student can	40–60%
• apply cause-and-effect reasoning to formulate relationships in which scientific evidence shapes or refutes a theory, and explain the limitations of science and technology in answering questions and solving problems	
• describe and evaluate the design and function of technological solutions to theoretical and practical problems, and relate the ways in which science and technology advance one another	
• evaluate from a variety of perspectives how science and technology are influenced and supported by society; assess the ability of society to interact responsibly with the environment	
• apply the skills and knowledge acquired in science to everyday life	

Examination Design

The design of the 2001–02 Chemistry 30 diploma examinations is as follows.

Question Format	*Number of Questions*	*Percent Emphasis*
Multiple Choice	44	55
Numerical Response	12	15
Written Response	2	30

The machine-scored portion of each examination contains both multiple-choice and numerical-response questions, some of which may be linked.

Some examination questions are organized into sets that relate to broad contexts. Therefore, a set of questions may assess students' ability to integrate several general learner expectations (GLEs). All questions will measure achievement of scientific knowledge; some will also measure achievement of scientific process and communication skills and/or STS connections.

Answers for multiple-choice questions are recorded in the first section of the machine-scored answer sheet, and answers for numerical-response questions are recorded in the second section on the same side of the same machine-scored answer sheet. Answers to the written-response questions are written directly in the examination booklet.

Multiple-choice questions are of two types: *discrete* and *context dependent*. A discrete question stands on its own without any additional directions or information. It may take the form of a question or an incomplete statement. A context-dependent question provides information separate from the question stem. Many of the multiple-choice questions are *context dependent*. A particular context may be used for more than one multiple-choice question as well as for one or more numerical-response questions.

Numerical-response questions are of three types: calculation of numerical values, selection of numbered events or structures from a diagram/list, and determination of a sequence of events.

Linked questions are included in the machine-scored portion of the examination. The correct answer for any machine-scored question will always be scored as correct. For linked questions, an answer from one question is used to complete the next question. If students answer the first question incorrectly but use that answer correctly to answer the second question, they will receive full marks for the second question.

Examples of linked questions may be found in the *Archived Bulletin Information* section of the web site.

The **written-response** portion of each Chemistry 30 diploma examination contains two questions: a closed-response question that is analytically scored and an open-response question that is holistically scored. Each question has a value of 15% of the examination.

The score assigned addresses the level of understanding demonstrated by the response, the completeness of the response, and the degree to which the response communicates the student's understanding of the chemistry principles involved in solving the problem.

Assessment of STS Connections

Chemistry 30 examination questions are intended to measure the students' understanding of chemistry concepts. Some questions also measure students' understanding and use of skills associated with scientific inquiry, and some questions have been designed to measure students' understanding of the connections between science and technology and among science, technology, and society. As a result, many questions measure how well students can apply the skills and knowledge they have acquired in science to everyday life.

Industries, businesses, and post-secondary institutions in Alberta have been helpful in providing real-life contexts for STS questions, as well as in making connections between real life and the curriculum. The development of test items, from the writing stage until they appear on an examination, may take a number of years. The contributions of the following institutions have enhanced the quality of the diploma examinations program in Alberta.

Royal Tyrell Museum, Drumheller
Concordia University College of Alberta
University of Alberta
University of Lethbridge

Names of past contributors may be found in the *Archived Bulletin Information* of the web site.

Reminders and Explanations

Data Booklet

Alberta Learning continues to receive a number of requests for English and French Chemistry 30 Data Booklets. These booklets are only available from the LRC (Learning Resources Centre) at 12360 – 142 St., Edmonton, T5L 4X9. The cost is approximately $13.50 for 35 copies. The Chemistry 30 Data Booklet will be available online on the Alberta Learning web site, http://www.learning.gov.ab.ca, as of September 2001.

New Format for Numerical-Response Questions

The Learner Assessment Branch has received a number of comments from teachers regarding numerical-response questions. In a number of cases, such as determining the $E°_{\text{net}}$ and the heat of formation, many students have difficulty determining whether the answer is positive or negative, which is an ability that some teachers have indicated is very important. We have field-tested a new format in which students have to indicate whether the response is positive or negative, and we have received positive comments from field-test teachers regarding it. This new format may appear on diploma examinations in the 2001–02 year. An example of the new format follows.

Positive/Negative Question and Solution

If the temperature of a water sample at 5.87°C decreases by 10.00°C, then the final temperature of the water sample will be

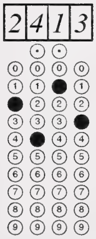
If + record **1**
If − record **2** ________ • ________ ________ °C

first column	**second** column	**third** column	**fourth** column

(**Note:** The placement of the decimal is provided, therefore record your **four digits** in the numerical-response section on the answer sheet.)

Answer –4.13 Record as 2413

Record 2413 on the answer sheet →



Familiarity with Numerical-Response Questions

Teachers and students should be familiar with the different types of numerical-response questions used on diploma examinations. Similar formats for numerical-response questions are used on diploma examinations for all of the sciences. Responses indicate that although most students appear to have been exposed to the different possible formats, some students have not had enough experience with them. Examples of the four formats that are currently used on chemistry diploma examinations follow. Examples will also appear on the instructions pages of diploma examinations in each of the sciences.

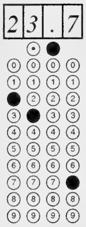
Calculation Question and Solution

The average of the values 21.0, 25.5, and 24.5 is ________.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

$$\begin{aligned}\text{Average} &= (21.0 + 25.5 + 24.5)/3\\ &= 23.666\\ &= 23.7 \text{ (rounded to three digits)}\end{aligned}$$

Record 23.7 on the answer sheet →



Correct-Order Question and Solution

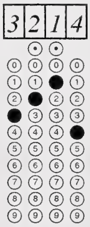
When the following subjects are arranged in alphabetical order, the order is ____ , ____ , ____ , and ____ .

1 physics
2 chemistry
3 biology
4 science

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

Answer 3214

Record 3214 on the answer sheet →



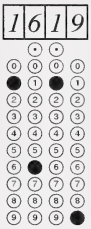
Scientific Notation Question and Solution

The charge on an electron is $-\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ C. The values of ***a***, ***b***, ***c***, and ***d*** are ____, ____, ____, and ____ .

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

Answer -1.6×10^{-19} C

Record 1619 on the answer sheet →



Positive/Negative Question and Solution

If the temperature of a water sample at 5.87°C decreases by 10.00°C, then the final temperature of the water sample will be

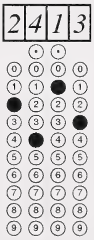
If + record **1**
If – record **2**

______	______ •	______	______ °C
first column	**second** column	**third** column	**fourth** column

(**Note:** The placement of the decimal is provided, therefore record your **four digits** in the numerical-response section on the answer sheet.)

Answer –4.13 Record as 2413

Record 2413 on the answer sheet →



Context Questions

Many of the questions used on diploma examinations are context-based or tied to a certain topic or area. We have received some comments from students and teachers who are not clear about when a set of related questions ends. As explained in the instructions at the front of the examination, a grey bar is used to indicate the end of a set. However, a grey bar is not used to indicate the end of a set if it is followed by a new set of questions.

Marking of the Written-Response Questions on Field Tests

The Learner Assessment Branch would like to express its gratitude to teachers and students who participate in the field-testing program. The field-testing program provides feedback on the strengths, validity, difficulty, and accuracy of potential diploma examination questions. These items are then considered for future diploma examinations. Another purpose of the field-testing program is to provide feedback to students on their potential strengths and weaknesses. We recognize the time constraints that teachers and students are under, and every effort is made to ensure that field tests are of top quality. However, in order to ensure validity of items, it is imperative that students take field tests seriously. Teachers are asked to review the written-response questions and to mark their students' responses in order to ensure validity of the questions, to identify any problems with the wording, to identify concerns related to students' understanding, and to provide feedback to their students. Therefore, supervisors have been instructed to provide ample opportunity, within security limits, for the teachers to mark the written-response questions. We recognize that in some cases, because of time constraints, it may be impossible for teachers to mark the written-response questions.

Heat of Combustion: $H_2O_{(l)}$ or $H_2O_{(g)}$

There appears to be some confusion as to whether a heat of combustion should form $H_2O_{(l)}$ or $H_2O_{(g)}$. When most substances undergo combustion, sufficient heat is released to convert any water produced from the reaction into water vapour. However, our data booklet specifies heats of formation at 25°C, which indicates that water liquid is formed. When heats of combustion are determined empirically, they are determined in a bomb calorimeter, and because of the low temperature change, the water produced is in liquid form. Often, a diploma examination question refers to a heat of combustion for a fuel such as propane in a barbecue or butane in a lighter. These examples represent reactions that are performed in an open environment and students should use water vapour as a product to determine acceptable values for the heat of combustion.

On future diploma examinations, the general principle that will be followed is that if combustion reactions are performed empirically in a bomb calorimeter, water liquid will be the product; and, if the combustion occurs in an ambient environment and a theoretical heat of combustion is to be determined, the product will be water vapour.

Terminology

There has been some confusion regarding the terminology used to refer to bases that can accept more than one proton. When the number of protons accepted is to be specified, terms such as "dibasic" or "tribasic" will be used on diploma examinations. The generic term used on diploma examination to refer to a substance that can accept more than one proton will be "polybasic." The term "polyprotic bases" has been found to be too confusing and will not be used on diploma examinations.

Thermometric Titration

Students are familiar with using an indicator to empirically determine the equivalence point of titration. Other methods such as measuring the change in temperature (thermometric titration) or the change in conductivity are also legitimate methods for determining the equivalence point of some acid–base titrations. A thermometric titration involves monitoring the temperature of the reaction mixture as the titrant is added.

Experimental Design versus Experimental Procedure

There appears to be some confusion about the level of specificity required when students are asked for an experimental design or an experimental procedure. An experimental design is a plan for obtaining an answer to a problem. It includes giving the relationship between the manipulated and responding variable and, where possible, setting the limits of the experiment. The plan should include the identification of the manipulated (independent), responding (dependent), and relevant controlled variables.

> *Sample question:* What is the relationship between the concentration of electrolyte solution and the voltage produced by a silver–zinc cell?
>
> *Sample response when asked for an experimental design:*
> A number of silver–zinc voltaic cells will be assembled. The concentration of one or both electrolytes will be varied to determine the effect of the concentration of electrolyte on the voltage produced.
> The manipulated variable is the concentration of the electrolyte. The responding variable is the voltage produced. The controlled variables are the volume of solution, the temperature of solution, the mass and purity of the electrodes, and the resistance of the voltmeter.

An experimental procedure is a step-by-step course of action used to investigate a problem. The experimental procedure should be more prescriptive and should include specific details regarding identity, concentration and volume of reagents, materials used, safety considerations, the pertinent measurements to be recorded, and when the experiment is to end.

Assessment of Communication Skills

Chemistry is a discipline in which there is a stringent set of rules for proper scientific communication. Communication skills are most evident and can be directly assessed on the written-response questions.

The closed-response analytic written-response question is marked out of 12, with 8 marks for chemistry content and 4 marks for communication. The communication mark is partially determined by the extent to which the question has been attempted. Communication is marked based on organization, clarity, use of correct scientific conventions, and use of proper language conventions.

Proper scientific conventions include
- sentence construction, grammar, and mechanics
- labelling of graphs and diagrams
- mathematical formulas and equations
- significant digits, units of measurement, and unit conversion
- states of matter
- abbreviations

The open-ended response (holistic) written-response question is marked using the new generic holistic scoring guide (see page 16), which integrates the assessment of communication skills into the marking matrix that is used to assess the overall response.

Therefore, on the analytic question, communication skills are assessed more independently; whereas, on the holistic question communication is assessed as part of the total response.

Communication Scoring Guide for Closed-Response (Analytic) Questions

Score	**Criteria (Scale 2)**
4	The marker does not have to interpret any part of the response, and no reference to the question is needed to understand the response. The response is clear, concise, and presented in a logical manner. All language and scientific conventions have been followed.
3	The marker may have to interpret part of the response or the response is poorly organized, but no reference to the question is needed to understand the response. There are no errors in the language and scientific conventions used. **OR** The marker does not have to interpret the response; however, there are errors in the language and scientific conventions used.
2	The marker has to interpret the response or the response is so poorly organized that the marker has to refer to the question in order to understand the response. The response may be ambiguous and/or disorganized, and there are errors in the language and scientific conventions used. **OR** The response is correct, clear, organized, and there are few/no errors in the conventions but only 50% or less of the question has been attempted.
1	The response is limited in length; however, the marker does not have to interpret the response. There are errors in the language and scientific conventions used.
0	The response is limited in length. The response is ambiguous and/or disorganized and contains errors in the language and scientific conventions used.
NR	No response given.

Scientific conventions to be followed:

- Correct, appropriate units are used throughout the response.
- States are given throughout the response except in calculation labels and when a formula replaces a word in a sentence.
- Significant digits are used throughout the response.

New Generic Holistic Scoring Guide

The Learner Assessment Branch sent a letter to all superintendents and high school principals regarding the November 2000 implementation of a new holistic scoring guide for Chemistry 30 and the January 2001 implementation for Physics 30.

The Learner Assessment Branch piloted these guides during August 2000 to validate them relative to the guides that have been used in the past. All indications are that the new guides helped teachers arrive at the same mark allocation as the older guides, but with greater efficiency.

Rationale for New Scoring Guide

The new single-scale scoring guide for the holistic question attempts to address the following issues.

- In the past, it has been difficult to reliably separate the communication scale from the content scale for the holistic question.
- Diploma markers often had to read a paper two or three times before awarding marks on the two scales. As a result, holistic marking has traditionally taken longer than analytic marking.
- Marking was moving away from the intended holistic approach toward a more analytic approach.
- The possibility existed for students with weak scientific convention usage to lose communication marks for the same error on both written questions.
- The two-scale scoring system was not easily transferable. Few teachers integrated the two-scale scoring system into their classroom assessment practice.

The new scoring guide for Chemistry 30 has the following characteristics.

- The format of the holistic item and the types of questions asked will not change. The questions will be designed so that students can demonstrate their understanding of science from more than one valid approach or perspective.
- The value of the holistic question will continue to be 15% of the examination mark.
- The communication and content scales are integrated into a single scale.
- The student responses will be assessed in a more holistic fashion.
- The holistic question will still be marked twice.

Two-Marker Scoring System

The open-response question is scored independently by two teachers using a holistic scoring guide. The guide describes the characteristics of students' answers that correspond to one of seven values: 0, 1, 2, 3, 4, 5, and 6. The descriptions used in the holistic scoring guide include criteria for assessing communication skills along with criteria for assessing science content.

If the scores for content obtained by the two independent markers vary greatly, the scores are classified as *discrepant*. Student responses that have *discrepant* scores are read by a third marker who assigns a mark.

Students should be familiar with *Directing Words* and *Process Words* when answering the written-response questions.

The new scoring guide employs a similar marking matrix to that of the previous two-scale holistic scoring guide. Markers must read the student response in its entirety in order to decide it if contains the key component for the particular question. The marker then looks for the necessary support details. These two aspects are used to assess the quality of students' responses. Communication skills and scientific conventions are considered in the determination of the overall quality of the key component and support arguments/procedures/algorithms.

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Generic Holistic Scoring Guide

Score	Criteria
6	The student demonstrates an **excellent** understanding of the **key component(s)** of the question and fully and correctly supports those components. The response • addresses all necessary arguments/procedures/algorithms in the key component(s) and its supports • demonstrates confident understanding of chemistry principles but may contain a few minor errors
5	The student demonstrates a **good** understanding of the **key component(s)** of the question and fully and adequately supports those components. The response • has more support arguments/procedures/algorithms that are correct than are incorrect or not covered • demonstrates competent understanding of chemistry principles but may contain minor errors
4	The student demonstrates a **competent** understanding of the **key component(s)** of the question. The response • has a minimum of one correct (or two partially correct) support arguments/procedures/algorithms
3	The student demonstrates a **basic** understanding of the **key component(s)** of the question. The response • does not contain an adequate support argument/procedure/algorithm **OR** In the response, the student **does not address** the **key component(s)** of the question. The response • contains more support arguments/procedures/algorithms that are correct than are incorrect or not covered
2	The student **does not address** the **key component** of the question or demonstrates poor understanding of the component. The response • has a minimum of one correct (or the equivalent of one) support argument/procedure/algorithm
1	The student **does not address** the **key component** of the question. The response • has a minimum of one correct partial support argument/procedure/algorithm
0	The response is incorrect and/or totally off topic.

Communication Guidelines

- Most appropriate scientific conventions, including the use of correct and appropriate units/significant digits/states, are followed.
- States may be absent if formulas replace words in the text of the response.
- The response should demonstrate good mechanics, grammar, and organizational skills.
  Communication for the open-ended, written-response question is dependent on the complexity and completeness of the response and is integrated into the awarded mark

The student exemplars that follow are from the January 2001 Chemistry 30 examination administration and were chosen to illustrate the interpretation of the new single-scale holistic scoring guide. In this written-response question, students were given five different antacids, the principal active ingredient(s) of each, and the neutralization reaction with stomach acid. The students were then asked to plan an experiment to test the effectiveness of antacids. They were also asked to include an experimental design, a data table, and three factors that should be considered when choosing an antacid.

Use the following information to answer the next question.

	Representative Antacid	**Principle Active Ingredient**	**Neutralization Reaction**
I	Alka-Seltzer	Sodium bicarbonate	$NaHCO_{3(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2CO_{3(aq)}$
II	Phillips' Milk of Magnesia	Magnesium hydroxide	$Mg(OH)_{2(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2\,H_2O_{(l)}$
III	Rolaids	Dihydroxyaluminum sodium carbonate	$Al(OH)_2NaCO_{3(s)} + 4\,HCl_{(aq)} \rightarrow AlCl_{3(aq)} + NaCl_{(aq)} + 2\,H_2O_{(l)} + H_2CO_{3(aq)}$
IV	Tums	Calcium carbonate	$CaCO_{3(s)} + 2\,HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2CO_{3(aq)}$
V	Di-Gel	Aluminum hydroxide	$Al(OH)_{3(s)} + 3\,HCl_{(aq)} \rightarrow AlCl_{3(aq)} + 3\,H_2O_{(l)}$
		Magnesium carbonate	$MgCO_{3(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_2CO_{3(aq)}$
		Magnesium hydroxide	$Mg(OH)_{2(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2\,H_2O_{(l)}$

— From *The Extraordinary Chemistry of Ordinary Things*, 1992

Written Response—15%

1. Plan an experiment to test the effectiveness of antacids.

Your response should include:

- an experimental design
- a data table for your experimental design
- three factors that should be considered when choosing an antacid

It should be noted that the new generic holistic scoring guide will only be applied to the holistic written-response question. To interpret the generic holistic scoring guide, each holistic question requires a definition of the question's key component(s) and the support arguments/procedures/algorithms necessary to achieve each of the performance standards.

The following table provides a sample response along with the identification of the key components and the support arguments/procedures/algorithms necessary to address the question.

<table>
<tr><th>Marks</th><th>Sample Response</th><th>Comments</th></tr>
<tr>
<td>6</td>
<td>
Experimental Design
A number of factors could be tested to determine the effectiveness of the antacids.
Sample factor to study: Using the same dose of active ingredient, determine which antacid neutralizes the most acid.
• Obtain the recommended amount of each antacid.
• Dissolve the antacid in 40 mL of deionized water. Add 2 to 3 drops of bromothymol blue indicator.
• Titrate the antacid with a strong acid ($HCl_{(aq)}$) of known concentration until a colour change occurs.
• Record the volume of $HCl_{(aq)}$ required for the pH to reach 7.
Controlled Variables
Dose of antacid sample
Concentration of acid, $HCl_{(aq)}$
pH at end point
Data Table
Record the volume and concentration of acid added until a change (pH, colour, bubbles) indicates when to stop.
<table>
<tr><th>Sample ID</th><th>Mass of Antacid (g)</th><th>Vol. of Acid (mL)</th></tr>
</table>
Factors to Consider
Mass of sample used; i.e., one is a big pill that must be swallowed
Liquid versus solid—ease of use
Low solubility; i.e., antacid does not react before it reaches the stomach
Cost factor, taste, toxicity, rate of reaction, or how exothermic the reaction is
Possible side effects of ingredients:
producing $H_2CO_{3(aq)}$ → more “gas” due to $CO_{2(g)}$ evolved
$Mg(OH)_{2(s)}$ or $CaCO_{3(s)}$ → strong bones need calcium
→ magnesium causes diarrhea
$Al(OH)_{3(s)}$ → linked to Alzheimer’s disease
$Na^+_{(aq)}$ → linked to heart disease
</td>
<td>
<i>Key Components:</i>
• An experimental design that could work including recognition of sample size, an indication of when to end the experiment, and the selection of appropriate reagent(s).
<i>Support:</i>
• Details of design (i.e. concentration, identity of acid, pH at end point, indicator color, initial pH)
• Data table (including manipulated and responding variables)
• Three factors
</td>
</tr>
</table>

The question required students to formulate an experiment that could work. In order to demonstrate understanding of the key component (a minimum score of 3 out of 6), students had to address three essential experimental features: the specific amount of antacid used in their experiment, a plan for determining the comparative effectiveness of the antacids (i.e., the identification of experimental variables), and an indication as to when the experiment ended. Most students reacted the antacids with an acid. Those who did so needed to define the type of acid (strong or weak) and to control volume and concentration of the acid in order to obtain full marks for addressing the key component.

Once the marker determines whether or not the response has addressed the key component, the response is then evaluated to determine the quality of the support arguments/procedures/algorithms. To achieve a score greater than 3 out of 6, the response must address three specific supports. The first support centres on quality or detail of specific items outlined in the experimental plan, such as identifying a specific acid, concentration and volume of acid, choice of indicator and its colour change, and specific titration set up. The second support examines the quality of the data table with respect to whether or not it includes the manipulated and responding variable. The third support addresses the other factors that should be considered when choosing an antacid. Each of these supports is multifaceted, thus a wide variety of unique, yet valid, solutions to this problem are possible. Therefore, markers have some discretion, based upon their interpretation of the quality of a student's response, in awarding different scores. It is sometimes difficult to differentiate between a response that has "good chemistry" that is poorly communicated, from a response with "poor chemistry" that is communicated well. Each response is scored by two different markers, and the final mark is an average of the two scores. If the two marks awarded are discrepant, a third marker will review and mark the response. This ensures that the response receives the fairest possible mark.

Limitations Involving this Question

Chemistry 30 students should have experience performing acid–base experiments to determine the concentration of one of the reagents.

- Given the nature of this type of question and students' limited experience with antacids, marks were awarded for experiments that **could** work rather than for procedures that necessarily **would** work.
- It was expected that students who chose to react the antacids would select stomach acid ($HCl_{(aq)}$); however, other strong monoprotic acids or $H_3O^+{}_{(aq)}$ were accepted.
- Students who used a titration experiment commonly indicated that a buret or a stock beaker of reagent was used, which implied that a constant concentration was employed. These students were given the benefit of the doubt regarding controlling the concentration of one of the reagents in this way.
- Given the limitations of the current chemistry curriculum, students were not expected to understand the solubility constant, thus the fact that many antacids are insoluble was overlooked.
- The term "experimental design" was interpreted in a number of ways. Students were not expected to write a detailed step-by-step procedure. They were, however, required to plan an experiment that involved addressing the experimental variables, identifying all necessary reagents, and outlining a method that could be employed to solve the problem.

The January 2001 *Chemistry 30 Examination Manager's Report* provided specific details regarding student achievement on this written-response question. This document is available on the Alberta Learning extranet.

Sample Student Responses

A number of sample responses are given on the following pages. For each, the score awarded and a rationale for that score are also provided. The responses were marked by classroom teachers using the new holistic scoring guide.

Exemplar 1
Score 5 to 6 out of 6

Problem: What is the effectiveness of each of the antacids listed in the chart above?

Hypothesis: ?

Materials:

- Alka-Seltzer
- Phillips Milk of Magnesia
- Rolaids
- Tums
- Di-gel
- hydrochloric acid (1.00 mol/L)
- beakers
- gloves
- eye protection
- aprons
- petri dishes

Procedure:

1) Get all materials
2) Prepare a 100 mL of 1.00 mol/L solution of HCl in each beaker
3) Measure the pH of the HCl solutions with a pH meter.
4) Prepare 100 g of each antacid, crush it into tiny pieces, and get ready to add to the HCl solutions.
5) Add 100 mL of each of the antacids to the beakers containing HCl.
6) Stir each solution and now measure the new pH.
7) Compare pH values for each sample.

Observations:

Antacid	pH of HCl	pH after	pH difference
Alka-Seltzer			
Phillips' Milk of Magnesia			
Rolaids			
Tums			
Digel #1			
Digel #2			
Digel #3			

Conclusion:
3 factors in choosing an antacid
1) The effectiveness in neutralizing the HCl solution.
2) The cost of each antacid compared to effectiveness.
3) Length of time needed to change the pH the most.

Exemplar 1 Rationale

The response contains a valid procedure in which the effectiveness of each antacid is determined by adding a measured amount of each antacid to a specific volume and concentration of hydrochloric acid. Therefore, the response addresses all of the key components of the question.

In terms of support arguments/procedures/algorithms, the response includes clear attention to the details of the procedure and is straightforward enough that the procedure can be used in a laboratory setting. The identity, concentration, and volumes of reagents are specified.

The mass of antacid used may be problematic as the response indicates that 100 g of an antacid would react completely with 100 mL of an acid solution. This amount of antacid is excessive and would most likely neutralize all of the acid but leave excess antacid. Therefore, a comparison based on this procedure may not be valid.

The response includes a data table that is consistent with the procedure, and it clearly indicates the change in pH as the criteria for comparison. The three factors identified are each unique. The third factor may be considered ambiguous by some markers.

A few grammatical errors were identified in the response, but most scientific conventions were followed appropriately.

This response clearly has more correct arguments than incorrect or not covered arguments. In order for a response to be awarded a score of 6, the marker has to be convinced that all aspects of the question have been adequately addressed. As a result of the concerns identified, one of the markers chose to award this response a score of 6 and the other marker a score of 5, which resulted in an overall score of 5.5 out of 6 for this question.

Exemplar 2
Score 4 out of 6

experimental design- To test the effectiveness of antacids you should design a titration experiment. For each antacid you should use a solution of hydrochloric acid ($HCl_{(aq)}$) with the same concentration and volume. Place the chosen antacid into the buret. Place an indicator into the HCl solution. Titrate and record results. After the titration, determine the volume it took to neutralize the acid. Do this with all the antacids and compare in a table.

- Note: be sure to make certain that you use the same concentration of antacids for each experiment.

Data Table: ex: $NaHCO_{3(s)} + HCl_{(aq)}$

← a table for each antacid

	Test 1	Test 2	Test 3
initial			
final			
difference			

antacids / volume	Alka-seltzer	Phillips Milk of Magnesia	Rolaids	Tums	Di-Gel
difference					

Factors when considering choosing an antacid:

- The antacid with the least amount of volume required to neutralize the $HCl_{(aq)}$ works the quickest.
- Some antacids may cause other side effects.
- Antacids don't all work the same way and the instructions should be read.

Exemplar 2 Rationale

The response contains a procedure in which a certain unspecified volume and concentration of hydrochloric acid is titrated with each antacid. This response, although vague, could work and therefore demonstrates a competent understanding of the key component. The response addresses the need for controlling the concentration and volume of the acid as well as the concentration of the antacid. The response uses a titration in which the antacid is in the buret; therefore, the volume of antacid is the responding variable. The volume of antacid used to neutralize the acid is clearly used to compare the antacids. Therefore, all parts of the key component are addressed and the response should receive a score greater than, or equal to, 3 out of 6.

In terms of support arguments/procedures/algorithms, the procedure is quite vague in a number of areas. Although the acid is specified, its concentration and volume is controlled but unspecified. The response also uses an unknown amount of an unspecified indicator. As well, the colour change is not given. The use of the antacid in the buret presents a number of problems in that the marker must assume that the solid antacids were made into solution prior to being placed in the buret. Although the response clearly indicates that the same concentration of antacid should be used for each trial, how this was to be done, given that most of the antacids are only slightly soluble, was not explained. Therefore, in terms of the details of the design, supporting arguments were not made.

The response includes a data table that lacks labels necessary to make the information self-explanatory. The marker has to infer what is being recorded in the chart by referring back to the procedure. In the second table, the student attempts to compare the different antacids, but again, the marker is required to infer what has been recorded. Therefore, this data table would only be considered a partial support of the procedure.

The first two factors considered in the response are valid; however, the first factor is problematic in that the antacid that neutralizes the most acid does not necessarily mean that it works the fastest. The last factor is too vague to be considered adequate.

This response has a number of partial supports that collectively add up to one correct support. This response was awarded a score of 4 because of the lack of correct or complete arguments/procedures/algorithms.

Exemplar 3
Score 3 out of 6

Experimental Design

I will dissolve each antacid in 100mL of water I will then titrate each mixture with a standardized $HCl_{(aq)}$ solution and measure the pH until equilibrium is reached. The solution that requires the most acid to reach equilibrium is the best antacid

Antacid	Amount of Standardized $HCl_{(aq)}$ required	pH at equilibrium
Alka-Seltzer		
Phillip's milk of magnesia		
Rolaids		
Tums		
Di-Gel		

Three factors to be considered when choosing an antacid are 1) any allergies you might have to it, 2) any side-effects of the antacid and 3) the price of this antacid.

Exemplar 3
Rationale

The student attempts to determine the effectiveness of each antacid by titrating a solution of each antacid with a standardized $HCl_{(aq)}$ solution. The response recognizes that the antacid should be dissolved before titration. The response also specifies that the hydrochloric acid is standardized, thereby implying that the concentration is known although the concentration is not specified. The response also states that the pH is measured until equilibrium is reached. The marker could infer that the student meant equivalence point rather than equilibrium. However, the response does not quantify the antacid and, together with the ambiguity of whether or not the concentration of acid is reasonable and with the improper use of equilibrium, this response has **not** sufficiently addressed the key component. Therefore, the highest mark this response could receive is 3 out of 6.

Scientific terminology is also used incorrectly in the data table where the “amount” is used to refer to the volume of $HCl_{(aq)}$. The data table does have a manipulated variable (the respective antacids) and a responding variable (the amount of $HCl_{(aq)}$). The factors to consider are valid. Although this response does not contain the necessary key components, it does have more supports that are correct than incorrect or unstated, and therefore received a score of 3 out of 6.

Exemplar 4
Score 2 out of 6

Experimental Design:

In this lab the effectiveness of five antacids will be tested. In order to do so, each antacid will be dropped seperatly into 5 different cups of fixed volume and concentration of hydrochloric acid. The results will be noted.

Data Table

Representative antacid:	Products:	Tests performed and Description of products:
1. AlkaSeltzer	$NaCl_{(aq)}$ + $H_2CO_{3(aq)}$	carbonic acid: blue litmus → red pH < 7 using pH meter, salt(aq) made
2. Phillips' Milk of Magnesia	$MgCl_{2(aq)} + 2H_2O_{(l)}$	water visible. milky substance ($MgCl_{2(aq)}$)
3. Rolaids	$AlCl_{3(aq)} + NaCl_{(aq)} + 2H_2O_{(l)} + H_2CO_{3(aq)}$	water visible, salt(aq) carbonic acid: blue litmus → red, pH<7 using pH meter
4. Tums	$CaCl_{2(aq)} + H_2CO_{3(aq)}$	carbonic acid: blue litmus → red, pH<7 using pH meter
5. Di-Gel	$MgCl_{2(aq)} + 2H_2O_{(l)}$	water visible, milky substance ($MgCl_{2(aq)}$)

Factors to be considered:

- How strong of an antacid you want: Knowing if your stomach is used to antacids
- The length of time it takes to work.
- The size of the caplets (Are you able to swallow them?)

Exemplar 4 Rationale

The student attempts to determine the effectiveness of the antacids by dropping each antacid into a "fixed volume and concentration of hydrochloric acid." There is no indication of how the effectiveness of each antacid will be measured. Although the concentration and volume of $HCl_{(aq)}$ are controlled, the amount of antacid used is unclear. Therefore, this response does not address the key component of the question and cannot receive a score greater than 3 out of 6.

Had this response provided a responding variable, such as the measurement of the final pH, and specified an amount of antacid, such as one tablet or one dose, the response would have been sufficient to be awarded marks for the key component.

In terms of supports, the student identifies hydrochloric acid as the reagent and controls the concentration and volume of the acid. The data table is not empirical in nature and does not appear to be related to the procedure. The factors provided are acceptable but lack detail. Although this response does not address the key component of the question, it does contain partial supports in the procedure and factors that collectively add up to the minimum one support required to achieve a score of 2.

This response would have been awarded a score of 1 if it contained only one correct partial support. Given that the criteria for scores are based upon correct content and communication, students did not receive marks for merely being on topic nor for providing responses that were well communicated but that had no correct chemistry content.

Archived Bulletin Information

Diploma Examinations Program

Alberta
LEARNING

Contents

Page 2 *Archived Bulletin Information*

Page 2 *General Reminders and Explanations by Year Introduced*

Page 7 *Electrochemistry*

Page 10 *Acid–Base/Equilibrium*

Page 13 *Thermodynamics*

Page 13 *Sample Linked Questions*

Page 15 *Sample Test Items, Scoring Criteria, and Sample Answers*

Archived Bulletin Information

The following are clarifications of the curriculum as specified in previous bulletins based on the Chemistry 20-30 Program of Studies (Interim 1998).

Each bulletin contains unique information of value to teachers, especially teachers new to the program. Information such as course clarifications, reminders and explanations, and definitions of terms that are relevant to the diploma examination program can be found in the *Archived Information* section of specific subject bulletins on the web site. Only information that is applicable to current diploma examination programs has been archived.

General Reminders and Explanations by Year Introduced

Data Booklets

Because of the number of errors in the 1995 version of the French Chemistry Data Booklet, a new version was available in September 1999. This 1999 version will be the standard used for diploma examinations starting with the November 1999 administration. (1999)

General Points

Alberta Learning has approved a new *Calculator Policy for Examinations* beginning in the 2000-01 school year. Chemistry teachers and students should be familiar with the complete calculator policy which is available on the Alberta Learning web site http://www.learning.gov.ab.ca. The Chemistry 30 Diploma Examination will require the use of a scientific calculator, or a graphing calculator approved by Alberta Learning. Please note the following from the new calculator policy. During examinations, teachers and students must ensure that

- calculators operate in silent mode
- students do not share calculators or information contained within them
- calculator cases are not available to students
- programmable calculator memories, including parametric memories, have been cleared
- only graphing calculators on the current list approved by Alberta Learning are used

(2000)

Difficulty Levels of Diploma Examination Questions

Teachers have expressed concerns regarding the validity of questions in which either 10% or 90% of the student population obtain the correct answer. There are a limited number of these questions on any diploma examination. Every effort is made to test the full range of the chemistry curriculum. Diploma examination questions are chosen based upon difficulty level, differentiating ability, and a number of other parameters. Questions at difficulty levels of 10% or 90% are valid and are useful in differentiating students meeting the *standard of excellence* as well as students who do not achieve the *acceptable standard.* (2000)

The *Chemistry 20-30 Program of Studies (1998)* indicates that students are required to perform calculations related to titration data including thermometric, redox, and acid-base systems. (1999)

The term's precision, readability, and accuracy will be used as defined by IUPAC. Precision refers to the reproducibility and not to "the place value of the last digit obtained in a measurement". The readability is the last place value of a measurement from a balance or measuring instrument. The term accuracy refers to the difference between a result and the true value. (1996)

Students are expected to perform calculations using the Ideal Gas Law. (1997)

Students are expected to be able to write net ionic equations for chemical reactions. (1997)

Students are expected to be able to solve linked questions. Some questions may include concepts from more than one of the units. (1997)

Scientific Process Skills

A number of terms used in the context of scientific process skill questions have confused some students. A sample of such terms with their preferred definitions follows. (2000)

Hypothesis is a single proposition intended as a possible explanation for an observed phenomenon; e.g. a possible cause for a specific effect.

Variables are conditions that can change in an experiment. Variables in experiments are categorized as:

- Manipulated variables (independent variables)- conditions that were deliberately changed by the experimenter.
- Responding variables (dependent variables)- conditions that changed in response to the change in the manipulated variables.
- Controlled variables (fixed or restrained variables)- conditions that could have changed but did not, because of the intervention of the experimenter. (2000)

Experiment—is a set of manipulations and/or specific observations of nature that allow the testing of hypothesis and/or generalizations. (2000)

Conclusion—is a proposition that summarizes the extent to which a hypothesis and/or theory has been supported or contradicted by the evidence. (1996)

Assessment of STS Connections

Students are expected to solve questions that relate directly to the nature of STS connections. (1995-7)

Students are expected to be able to determine the meaning of potentially unfamiliar words from the context in which they are used. (1996)

Chemistry 30 examination questions are intended to measure the students' understanding of concepts. Some questions also measure students' understanding and use of skills associated with scientific inquiry, and some questions have been designed to measure students' understanding of the connections between science and technology and among science, technology, and society. As a result, many questions measure how well students can apply the skills and knowledge they have acquired in science to everyday life. (1999)

Industries, businesses, and post-secondary institutions in Alberta have been helpful in providing real-life contexts for STS questions, as well as in making connections between real life and the curriculum. The development of test items, from the writing stage until they appear on an examination, may take a number of years. The contributions of the following institutions have enhanced the quality of the diploma examination program in Alberta (1999-2000).

API Grain Processors, Red Deer
Banff Wastewater Treatment Plant, Banff
Bonnybrook Water Treatment, Calgary
Bow Valley Brewing Company, Canmore
Concordia University College of Alberta
High Wood Distillers Ltd., High River
Imperial Oil Resources Ltd., Calgary
Kawneer Canada Ltd., Lethbridge
Lethbridge Iron Works, Lethbridge
Prairie Chemical Inc., Edmonton
Royal Tyrell Museum, Drumheller
Syncrude, Fort McMurray
Texas Instruments
University of Alberta
University of Lethbridge
Wascana Energy, Balzac

The related general outcome for skills states: “Students will be expected to develop an ability to use thinking processes associated with the practice of science for understanding and exploring natural phenomena, problem solving and decision making,” and, when “evaluating the process or outcomes,” students are to “consider consequences and biases, assumptions, and *perspectives*.” (1999)

The related general outcome for STS connections states: “Students will be expected to explain and evaluate for a given instance, and *from a variety of given perspectives* how science and technology are influenced and supported by society; and assess the ability and responsibility of society, through science and technology, to protect the environment and use natural resources wisely.” (1999)

Societal decision making is informed by many other interest areas, for example, science, technology, politics, and ethics, which are generally referred to as perspectives. Specific outcomes in the program of studies, such as those requiring students to assess the risks and benefits of a societal decision, provide opportunities for students to practice considering perspectives on issues related to science. The following list of perspectives, while not exhaustive, can provide guidance for teachers in their instruction and assessment of students. STS perspective questions can be asked in any of the three Chemistry 30 units. (1999)

Perspective	**This perspective relates to:**
Scientific	the current knowledge, research, concepts, or theories of science
Technological	the processes and products that result from the human desire to change the world to better serve our needs
Ecological/ Environmental	the balance in the biosphere of the relationships among living systems and of living systems with their environment
Economic	the production and distribution of wealth
Political	the policies, laws, and programs of government
Legal	the laws of a jurisdiction
Societal	the community, its culture, and human relations
Ethical	considerations of what is right or wrong

Sample Perspective Question

7. “The use of fossil fuels as an industrial energy source contributes to global warming.” This statement is made from a perspective that is primarily

A. scientific
B. political
C. economic
•D. ecological

Conventions (Skill) Assessment of Written Responses

The intent of evaluating communication is to reward students for creating responses that are on topic, clear, concise, and well written using the conventions of scientific language. Conventions (skill) assessment on the chemistry diploma examinations will focus on three main criteria

Units used should respect the conventions of the International System of Units (SI). A list of some of these symbols can be found in the data booklet. Many students continue to use unit abbreviations indiscriminately; for example, time in seconds as sec. instead of s, or hours as hrs. Unit problems and/or omissions are considered communication errors. (1999)

Student responses on the written-response questions will continue to be evaluated on how well the response is communicated. (1997)

Markers of Chemistry diploma exams have made the following comments about communication conventions. (1995)

- "Shorthand" should not be used for written response because there is no guarantee that a specific teacher's/student's shorthand notation will be understood by all markers.
- The "box" method of stoichiometry is **not** an acceptable method of communicating an answer and should **not** be used in the written response section of the examination.
- Proper terminology should be used; pH not Ph, molar heat (enthalpy) of reaction **not** reaction heats.

During field-test marking, it was noted that a number of students record e^{-7} for 10^{-7} when providing written-response answers in scientific notation. This is **not** an appropriate scientific convention; thus, students could lose communication marks for this error. (1999)

Written response questions will require students to see relationships among concepts learned and require students to supply appropriate contexts. (1997)

When performing calculations, students are expected to use the values of the constants or referenced values provided in the data booklet and **not** the values programmed in a calculator. (1999)

For written-response questions, significant digits will be considered for the final answer only. Units must be present throughout the entire written-response question to receive full communication marks. (1999)

States of matter in equilibrium expressions should be applied consistently; either include all states or no states for full communication marks. E.g

$$K_a = \frac{[H^+][A^-]}{[HA]} \quad \text{or} \quad K_a = \frac{[H^+_{(aq)}][A^-_{(aq)}]}{[HA_{(aq)}]}$$

Students should have a working knowledge of mega and kilo prefixes. Conversion for less commonly used prefixes will be provided. (1999)

Students are advised to review the meaning of directing words as defined in Appendix C. These words will be used in the instructions given for responding to most items in the examinations, particularly in the written-response section. (1997)

Numerical-Response Questions

There is an ongoing effort to align the format of science diploma examinations. The field testing of the following format for numerical-response questions has been very successful and is currently used in Physics 30. Students will be expected to be familiar with this format on future Chemistry 30 diploma examinations. (2000)

Use the following information to answer the next question.

> When 20.0 mL samples of sodium hydroxide solution are titrated with 0.15 mol/L $HCl_{(aq)}$, the average volume of $HCl_{(aq)}$ used was 12.3 mL.

The concentration of sodium hydroxide used in this titration, in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ mol/L. The values for ***a***, ***b***, ***c***, and ***d*** are _____, _____, _____, and _____.

(Record your **four-digit answer** in the numerical-response section on the answer sheet.)

The number of digits to be recorded for each numeric-response questions is designated. Many students continue to record fewer digits than the designated number: this results in no marks being awarded for the response. Numeric response questions specify that answers are recorded to three digits (not three significant digits); for example, 0.01 has three digits. (1999)

Numerical answers are to be rounded only once, at the end of the question. Intermediate numbers are to be used as displayed on the student's calculator. For linked questions, answers are to be rounded at the end of each question. Thus, the value used in the linked question should be the rounded value, since linked questions are not one question but a series of independent items. (1997)

Electrochemistry

Oxidation Number or Oxidation State

The *Chemistry 20–30 Program of Studies, 1998*, states that students should be able to assign oxidation numbers to the species that undergoes a chemical change. Teachers have expressed some concern as to the depth to which this concept should be covered. Students are expected to have some sophistication in assigning oxidation numbers in order to identify and balance redox reactions.

Students should be able to determine the oxidation numbers for elements in compounds including oxygen in peroxides and hydrogen in metal hydrides. In molecular compounds, students should be able to determine the oxidation number for binary molecular compounds and for simple organic molecules and carbohydrates such as sucrose and glucose. Students are **not** expected to be able to assign different oxidation numbers to two atoms of the same element within a compound. For example, each of the carbons in $CH_3COOH_{(aq)}$ would be assigned an oxidation number of 0. Students are **not** expected to assign oxidation numbers to elements in molecular compounds containing a number of different elements such as urea ($CO(NH_2)_{2(s)}$) or nitromethane ($CH_3NO_{2(s)}$). Students are expected to be able to assign oxidation numbers for simple ionic compounds, complex ions, binary acids, and oxoacids. (2000)

"Oxidation number" and "oxidation state" will be used synonymously. Students are expected to assign oxidation numbers to hydrides and peroxides. (1997)

Students are expected to devise a balanced half-reaction in an acidic or neutral solution. They will be expected to balance chemical equations that occur in basic environments, but not to devise their own half reactions. (1997)

Students are expected to balance disproportionation reactions given the reagents involved. (1997)

Auto-oxidation versus Disproportionation

The term auto-oxidation and disproportionation will no longer be used synonymously on future chemistry diploma examinations. Only the term "disproportionation" will be used to describe a substance undergoing both an oxidation and a reduction. For the French translation of the diploma examination, the term "dismutation" will be used. (2000)

Identifying Redox Reactions

Students are expected to classify reactions where more than one species undergoes reduction or oxidation. An example of this type of oxidation–reduction reaction is

$$2\,Fe_2S_{3(s)} + 6\,H_2O_{(l)} + 11\,O_{2(l)} \rightarrow 4\,FeO_{(s)} + 6\,SO_4{}^{2-}{}_{(aq)} + 12\,H^+{}_{(aq)}$$

Students are **not** expected to balance this equation but are expected to be able to determine which species are oxidized or reduced. In the above equation, the Fe and O are both reduced and the S is oxidized. (2000)

Chloride Anomaly

Students are expected to be familiar with the chloride anomaly that occurs during the electrolysis of solutions containing the chloride ion and water as the strongest reducing agents. A common misconception is that if the minimum voltage for the electrolysis of water were applied, then the oxidation of water would occur rather than the oxidation of chloride ions. This is **not** correct. According to Zumdahl (*Chemistry*, Third Edition, pp. 817–843), the reduction potentials found on the reduction potential table are determined by comparing the reduction potential of a given half-cell to the standard hydrogen half-cell. The standard hydrogen reduction potential is the reference potential against which all half-reaction potentials are assigned. This is how the reduction potentials for oxygen and hydrogen ions (+1.23V) and chlorine (+1.36V) half-cells are obtained. During electrolysis, the theoretical minimum voltage is the difference in reduction potential between the oxidizing agent and the reducing agent. An excess voltage, called the overvoltage, is required in order for a reaction to occur. For example, as the voltage to a standard sodium chloride electrolytic cell is increased, the chloride ions are oxidized first. This is because the overvoltage for the oxidation of water is greater than is the overvoltage for the oxidation of chloride ions. A much higher potential than expected is required to oxidize water. Basically, the phenomena is caused by difficulties in transferring electrons from the species in the solution to the atoms of the electrode across the electrode-solution interface. Because of this situation, $E°$ values must be used cautiously when one is predicting the actual order of oxidation or reduction of species in an electrolytic cell. The chloride anomaly is the only anomaly with which students are expected to be familiar. (2000)

Classifications

"Electrochemical cells" will be defined as either voltaic cells or electrolytic cells. The term galvanic will not be used on the diploma exam. (1997)

Line or cell notation is used to describe electrochemical cells. On past diploma examinations, anode and cathode substances were indiscriminately placed on either side of the double vertical lines that designate the porous boundary separating two half-cells. The convention that will be used on future diplomas will be as follows: the substance constituting the anode is listed at the far left and the substance constituting the cathode is listed at the far right. (1999)

Standard state conditions and corresponding $E°$ values imply the use of 1.0 mol/L reagents. The larger the concentration of the reactants, the larger the $E°$ value. The Nernst equation would be required to calculate $E°$ values as a function of reactant and product concentrations in a redox reaction and is beyond the scope of the Chemistry 30 *Program of Studies*. However, students should know that as the reaction proceeds, the voltage generated will decrease as reactants are converted to products until reaching equilibrium at which point the battery "dies". (1999)

For half-cells containing acidified solutions (such as acidified potassium permanganate and an inert electrode), each half-cell should include **all** the active components in their standard state; that is, 1.0 mol/L $H^+_{(aq)}$, 1.0 mol/L $MnO_4{}^-{}_{(aq)}$, and 1.0 mol/L $Mn^{2+}{}_{(aq)}$. Together with an iron half-cell, the line notation is represented as

$Fe_{(s)}$ / $Fe^{2+}{}_{(aq)}$ // $MnO_4{}^-{}_{(aq)}$, $Mn^{2+}{}_{(aq)}$, $H^+{}_{(aq)}$ / $Pt_{(s)}$ (1999)

Students are expected to be able to determine the meaning of potentially unfamiliar words from the context in which they are used. For example, electrowinning, sacrificial anode, and cathodic protection are all terms that refer to eletrolytic systems. (1997)

Acid–Base/Equilibrium

Magnitude of K_{eq}

When predicting if reactants or products are favoured in reversible reactions, the magnitude of the K_{eq} value is only a general guideline. In a number of chemistry textbooks, there is a statement to the effect that a value of K_{eq} greater than one means that the products are favoured and a K_{eq} less than one means reactants are favoured. This is valid if a reaction has the same number of reactant and product molecules in the balanced chemical equation. When the number of reactant and product molecules are not the same, the value of the K_{eq} may be misleading in determining the extent of reaction. An analysis of the extent to which reactants are converted to products may be a better indication of whether reactants or products are favoured. (2000)

Pressure Changes and Le Châtelier's Principle

There is some confusion about the ways in which pressure can be increased and how it will affect an equilibrium system. Three methods to increase pressure are: reducing the volume of the reaction container, adding an inert gas, and adding a reactant or product gas. (2000)

- Increasing the pressure by reducing the volume of the container causes the system to alleviate the increased pressure by reducing the total number of gaseous molecules in the system. Equilibrium will therefore shift to the side with the least number of total gas molecules.
- Adding an inert gas increases the total pressure but has no effect on the concentration or partial pressures of the individual reactants or products. Therefore, there is no shift in the equilibrium.
- Adding a reactant or product gas will shift the equilibrium away from what is added and toward what is removed.

Buffer Systems

Students are required to recognize that a buffer system is composed of a conjugate acid–base pair (made of a weak acid and a weak base) that maintains a nearly constant pH when diluted or when small amounts of strong acid or strong base are added. (1999)

Amphiprotic and amphoteric substances will be used synonymously to describe substances that can act as either proton acceptors or proton donors. (1999)

Students are expected to calculate the pH of a buffer solution given the concentration of the conjugate acid base pair and or utilizing K_a. (1999)

Students are **not** expected to be able to predict whether or not a reaction is quantitative. However, this is not meant to discourage the teaching of this concept. Students should be able to recognize when a reaction is quantitative from information provided to them. (1997)

Students are expected to know that $K_a \times K_b = K_w$ (1997)

Students will **not** be expected to solve questions utilizing the quadratic equation. However, it is expected that the student set up the relationship correctly and only when the mathematical operation is to take place is a statement about approximation to be made and used. However, this is not meant to discourage the teaching of this concept. Furthermore, a student will be expected to use a quadratic equation to solve a question in the written response section of the examination if the student selects an acid to an open ended question for which an approximation cannot be made. No student will be penalized on any portion of the examination for using the quadratic equation to solve the problem. (1997)

The use of the approximation to solve acid-base equilibrium expressions is only acceptable when solving of the equation results in a quadratic expression and the original concentration of the acid or base is one thousand fold greater than the K_a or K_b. (1997)

Students are expected to determine the pH at the equivalence point of a reaction, and at different volumes after the equivalence point has been reached. (1997)

Students are expected to be as familiar with calculations involving K_b as they are for K_a. (1997)

Students are expected to know the term's "equivalence point" and "end-point". Equivalence point refers to the point when stoichiometric amounts of reactants are added together. Thus a "diploma type question" may ask students to indicate on the graph where the equivalence point for the reaction occurs. The term end-point will be used within a context of an indicator; for example, 40.2 mL was used to titrate the sample to the bromothymol blue (indicator) end-point. (1996)

Students will **not** be expected to solve questions using percent reactions. However, students are expected to be able to determine the percent reaction of any reaction. (1996)

Color charts for common aqueous ions and acid-base indicators may be used for approximate pH/colors. Answers to examination questions will be based on the indicator chart on page 10 of the data booklet. (1997)

Students are expected to predict how a wide range of factors affect equilibrium and/or the equilibrium constant.

> Students are expected to write equilibrium expressions for homogeneous and heterogeneous equilibria. The diploma examination will employ the convention of including in equilibrium expressions only substances that can vary in concentration.
> Gases must be included since the concentration of a gas can be altered by varying the pressure on it.
> For example, $CO_{(g)} + H_2O_{(g)} \Leftrightarrow CO_{2(g)} + H_{2(g)}$
>
> $$K_{\text{eq}} = \frac{[H_{2(g)}][CO_{2(g)}]}{[CO_{(g)}][H_2O_{(g)}]}$$
>
> Aqueous ions and/or gases in solution must be included since the concentration of aqueous ions and/or gases can be altered by varying the volume of solvent.
> For example, $N_2H_{4(g)} + H_2O_{(l)} \Leftrightarrow N_2H_5{}^+{}_{(aq)} + OH^-{}_{(aq)}$
>
> $$K_{\text{eq}} = K_b = \frac{[N_2H_5{}^+{}_{(aq)}][OH^-{}_{(aq)}]}{[N_2H_{4(g)}]}$$
>
> Pure solids are not included since the concentration (density) cannot be varied.
> For example, $2\,NaHCO_{3(s)} \Leftrightarrow Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$
>
> $$K_{\text{eq}} = [CO_{2(g)}][H_2O_{(g)}]$$
>
> Pure liquids are not included since the concentration (density) cannot be varied.
> For example, $2\,H_{2(g)} + O_{2(g)} \Leftrightarrow 2\,H_2O_{(l)}$
>
> $$K_{\text{eq}} = \frac{1}{[H_{2(g)}]^2[O_{2(g)}]}$$

Mixtures of liquids must be included since the concentration can be varied by changing the relative amounts of the mixed liquids. For example, $C_6H_{6(l)} + Br_{2(l)} \Leftrightarrow C_6H_5Br_{(l)} + HBr_{(l)}$

$$K_{\text{eq}} = \frac{[C_6H_5Br_{(l)}][HBr_{(l)}]}{[C_6H_{6(l)}][Br_{2(l)}]} \text{(1997)}$$

Thermodynamics

Students are **not** expected to solve questions utilizing $\Delta E_p = vc\Delta t$. This requires the use of density and implies that a volumetric measure such as gas volumes, would be appropriate. The expansion of the curriculum through this interpretation is not appropriate or valid. This concept is also flawed, in that specific heat capacity is a measure based only on mass and hence "vc" has no meaning. Additionally, the use of volume is problematic in that volume is temperature dependent, like "c". (1997)

Students will be required to distinguish between fission and fusion reactions. They should be able to recognize the fusion reaction that takes place on the Sun. To avoid confusion between phase and nuclear changes, the terms nuclear fission and nuclear fusion will be used. (1997)

Students are expected to balance nuclear equations for nuclear fission and nuclear fusion reactions. (1997)

Students are expected to recognize the contribution translational, rotational, and vibrational motion makes to energy changes i.e. kinetic energy. (1997)

Sample Linked Questions

The correct answer for any machine-scored question will always be scored as correct. For linked questions, an answer from one question may be necessary to complete the next question. If students answer the first question incorrectly but use that answer correctly to answer the second question, they will receive full marks for the second question. (1999)

To illustrate by example, multiple-choice question 22 and numerical-response questions 4 and 5 on the January 1999 Chemistry 30 Diploma Examination are of this type. (1999)

Examples of Linked Items

Use the following information to answer the next three questions.

> A student dipped 12.50 g strips of four different metals, $Ag_{(s)}$, $Cu_{(s)}$, $Pb_{(s)}$, and $Mg_{(s)}$, into a beaker containing 250 mL of 1.00 mol/L $HCl_{(aq)}$ in order to determine an activity series. One of the metals reacted immediately and vigorously with the acid.

22. The balanced net-ionic equation for the first reaction that occurred is

A. $2\,Ag_{(s)} + 2\,H^{+}_{(aq)} \rightarrow H_{2(g)} + 2\,Ag^{+}_{(aq)}$
B. $Cu_{(s)} + 2\,H^{+}_{(aq)} \rightarrow H_{2(g)} + Cu^{2+}_{(aq)}$
C. $Pb_{(s)} + 2\,H^{+}_{(aq)} \rightarrow H_{2(g)} + Pb^{2+}_{(aq)}$
•**D.** $Mg_{(s)} + 2\,H^{+}_{(aq)} \rightarrow H_{2(g)} + Mg^{2+}_{(aq)}$

Use the answer selected for ***Multiple Choice 22*** *to answer* ***Numerical Response 4.****

Acceptable Linked Question Responses

If MC22 is A, then NR4 is 0.80
B, then NR4 is 0.34
C, then NR4 is 0.13
•D, then NR4 is 2.37

Numerical Response

4. The electrical potential for this reaction is +/– __________ V.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the answer selected for ***Multiple Choice 22*** *to answer* ***Numerical Response 5.****

If MC22 is A, then NR5 is 12.5
B, then NR5 is 7.94
C, then NR5 is 12.5
•D, then NR5 is 3.04

Numerical Response

5. The mass of metal that reacted with the hydrochloric acid is __________ g.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if Multiple Choice 22 was answered incorrectly.**

Sample Test Items, Scoring Criteria, and Sample Answers

Sample Test

This shaded text indicates that there are a series of questions to follow which are based upon the scenario/context/STS introduction. In this case, there is a series of questions based upon the chemistry involved in the making of ice tea in the home.

Iced tea has become very popular over the last several years. As a result, there are many manufacturers producing and selling ice tea products. Unlike most "pops," ice tea is easily prepared at home. In order to prepare iced tea from scratch, the following steps are involved:

Step	Procedure
I.	A kettle containing cold water is plugged into an electrical outlet and left until the water has boiled for several minutes.
II.	The boiling water is poured into a teapot.
III.	Tea bags are added to the teapot and allowed to sit for several minutes before the bags are removed.
IV.	The hot tea is then poured into a container; sugar, lemon juice, and ice are added and mixed. The tea is placed in a refrigerator.

Multiple-choice question 1 (MC1) can only be answered by using information contained in the context. This question tests Unit 1–Concept 1: "explaining what is meant by the energy change of a system in terms of heating and cooling, thermal equilibrium, temperature change, phase change, forces between particles, particle movement and heat content." MC1 involves both a skill and STS component. It is expected that only students at the standard of excellence will be able to answer this question. The difficulty for this item is 19.3%.

1. In which step does the tea undergo an increase in kinetic energy?

A. I
B. II
• **C.** III
D. IV

Question MC2 requires the student to utilize information contained in the context. This question involves the same major concept, skill, and STS component as MC1 but it is expected that students at the acceptable standard will be able to answer this question. The difficulty for this item is 45.7%.

2. In the preparation of iced tea, where is there an increase in potential energy?

A. Step I only
B. Step II only
C. Steps II and III only
• **D.** Steps I and IV only

3. In which step is a temperature change of one of the components required to cause a change in potential energy of another component in the iced tea?

A. I

B. II

C. III

• **D.** IV

4. When a few drops of lemon juice is added to the tea, the colour of the solution changes. The main reason for the change in colour is that the

A. lemon juice dilutes the tea

• **B.** lemon juice is acidic and the tea acts as an acid-base indicator

C. tea is basic and the lemon juice acts as an acid-base indicator

D. hydronium (hydrogen ion) in the lemon juice reduces the tea

5. While making iced tea, a person's hand is burned from steam from the kettle. The burn is far more severe than a burn from the kettles' hot water would be because

A. a phase change is always exothermic

B. a phase change is always endothermic

C. condensing steam absorbs more energy from the surroundings than does an equivalent amount of hot water

• **D.** hot water releases less energy to the surroundings than does an equivalent amount of steam

Like the preceding two questions, this question requires the student to utilize information contained in the context. It also involves the same major concept, skill, and STS components. Like MC2, it is expected that students at the acceptable standard will answer correctly. The difficulty for this questions 64.3%.

Question MC4 is relevant to this context and tests a concept from a different unit, specifically Unit 3 Concept 3: "defining and describing indicators and explaining their colour changes in terms of an equilibrium shift." It is expected that students at the acceptable level will be able to answer the question successfully. The difficulty for this item is 61.3%

Question MC5 does not require the student to utilize specific information contained in the context but is relevant to the situation and is generalizable to other situations. It involves the Unit 1 Concept 1: "comparing phase, chemical, and nuclear changes in terms of magnitudes of energy involved" and has the same expectation as the previous questions. The difficulty for this question is 66.9%.

These questions demonstrate that at both the acceptable level and the standard of excellence there are a range of difficulties. These questions do not involve chemical concepts/knowledge unique to the new program of studies.

The next five questions are not in a scenario or context, but are selected to typify questions that can be expected to be found outside a scenario/context grouping. Several of these questions contain a common theme and could have been placed within a relevant scenario/context.

Question MC6 does not involve chemical concepts/knowledge unique to the new program of studies and addresses Unit 1 Concept 1: "using standard heats of formation table to predict heat of reaction for a chemical change." It is expected that students at the acceptable level will successfully answer this question. However, this question typifies the variety of methods of solving questions. The student at the acceptable standard may use long, time-consuming calculations to answer the question, whereas it is expected that a student at the standard of excellence could derive the correct answer without performing a single calculation. The difficulty of this item is 79.7%.

Question MC7 involves chemical concepts/knowledge unique to the new program of studies from the Unit 2 Concept 1 STS connection involving: "comparing oxidation-reduction reactions in living and non-living systems." The expectation for this question is that students at the acceptable level will be successful. The difficulty of this item is 82.3%.

Question MC8 involves chemical concepts/ knowledge unique to the new program of studies from Unit 1 Concept 1: "comparing cellular respiration represented by the simple equation: $6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)} + 6O_{2(g)}$ to the combustion of fuels." The expectation for this question is that students at the acceptable level will be successful. The difficulty of this item is 68.0%.

6. The energy stored in hydrocarbons can be released by combustion. When one mole of each of the following fuels is burned to form gaseous products, which fuel releases the greatest amount of energy?

A. butane

B. ethane

• **C.** pentane

D. propane

7. Which source of energy contributes to the greenhouse effect?

A. solar cells

B. nuclear reactors

C. hydroelectric power plants

• **D.** coal-fired power plants

8. Select the **false** statement.

A. Photosynthesis is an example of light energy converted into chemical energy.

B. Combustion of hydrocarbons is an example of chemical energy converted into heat and light energy.

• **C.** The glow of a firefly is an example of light energy converted into chemical energy.

D. The operation of a dry cell battery is an example of chemical energy converted into electrical energy.

9. Plants remove carbon dioxide from our atmosphere during photosynthesis. The balanced chemical equation for the reaction is

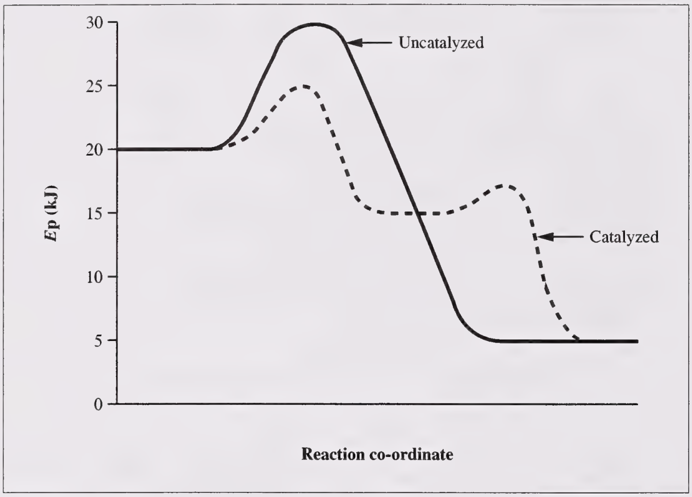
• **A.** $6\ CO_{2(g)} + 6\ H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)} + 6\ O_{2(g)}$

B. $6\ CO_{2(g)} + 6\ H_{2(g)} \rightarrow C_6H_{12}O_{6(s)} + 3\ O_{2(g)}$

C. $6\ CO_{2(g)} + 6\ H_2O_{(l)} \rightarrow C_6H_{12}O_{2(s)} + 8\ O_{2(g)}$

D. $12\ CO_{2(g)} + 11\ H_2O_{(l)} \rightarrow C_{12}H_{22}O_{11(s)} + 12\ O_{2(g)}$

Use the following graph to answer the next question.



10. The ΔE_p for the forward catalyzed reaction would be

A. –5 kJ

B. –10 kJ

• **C.** –15 kJ

D. –20 kJ

Question MC9 involves chemical concepts/knowledge unique to the new program of studies from Unit 1 Concept 1: “explaining how energy stored as potential energy in the chemical bonds of fossil fuels originate in the sun and is converted by the process of photosynthesis in living plants represented simply as : $6CO_{2(g)} + 6H_2O_{(l)} \rightarrow C_6H_{12}O_{6(s)} + 6O_{2(g)}$.” The expectation for this question is that students at the acceptable level will be successful. The difficulty of this item is 68.0%.

This question involves chemical concepts/knowledge unique to the new program of studies from Unit 1 Concept 1: “explaining that catalysts provide an alternative pathway for chemical changes without affecting the net amount of energy produced or absorbed.” The expectation for this question is that students at the acceptable level will be successful. The difficulty of this item is 71.2%.

The shaded text indicates a new series of questions that are based upon a scenario/context/STS. In this case, there is a series of questions based upon the chemistry of a breathalyzer.

Question MC11 does not involve chemical concepts/knowledge unique to the new program of studies. It is expected that students at the acceptable level will successfully answer this question. The difficulty of this item is 44.0%.

Question MC12 involves chemical concepts/knowledge unique to the new program of studies from Unit 2 Concept 1: "writing and balancing equations for oxidation-reduction reactions." The expectation for this question is that students at the standard of excellence will be successful since this questions requires the student to create their own half-reactions. The difficulty of this item is 35.9%.

Question MC13 involves chemical concepts/knowledge unique to the new program of studies from Unit 3 Concept 1: "writing and interpreting chemical reaction equations for chemical systems at equilibrium." The expectation for this question is that students at acceptable standard will be successful. The difficulty of this item is 57.4%.

Note: Questions 11 and 13 would not appear together on an examination since question 13 answers question 11.

The breathalyzer test is used to determine blood alcohol content. The alcohol vapour in breath is analyzed by its reaction with acidified potassium dichromate represented by the unbalanced equation:

$$Cr_2O_7^{2-}{}_{(aq)} + C_2H_5OH_{(g)} + H^+_{(aq)} \rightarrow Cr^{3+}_{(aq)} + CH_3COOH_{(aq)} + H_2O_{(l)}$$

The extent of reaction is proportional to the amount of alcohol in the breath sample and to the blood alcohol content.

11. If a sample containing alcohol was tested, one would expect the colour of the test sample to become more

A. blue
• **B.** green
C. orange
D. yellow

12. When the equation is balanced, using whole numbers, the coefficient of $H^+_{(aq)}$ is

A. 8
B. 12
C. 14
• **D.** 16

13. The amount of alcohol in the breath sample is most likely determined by the

• **A.** colour change of the solution
B. change in density of the solution
C. voltage produced by the reaction
D. conductivity of the solution

14. Which of the following empirical characteristics could **not** be used to show that equilibrium has been attained in a system?

A. colour constant
B. pressure constant
• **C.** mass constant
D. temperature constant

Use the following information to answer question 15.

$$PCl_{3(g)} + Cl_{2(g)} \rightleftharpoons PCl_{5(g)} \quad K_{eq} = 0.18$$

15. If a 1.00 L container with 1.00 mol of $PCl_{3(g)}$, 1.00 mol $Cl_{2(g)}$ and 1.00 mol $PCl_{5(g)}$ is allowed to reach equilibrium, the flask would contain

• **A.** more $PCl_{3(g)}$ and $Cl_{2(g)}$ than $PCl_{5(g)}$
B. more $PCl_{3(g)}$ and $PCl_{5(g)}$ than $Cl_{2(g)}$
C. more $PCl_{5(g)}$ than $PCl_{3(g)}$ and $Cl_{2(g)}$
D. more $Cl_{2(g)}$ and $PCl_{5(g)}$ than $PCl_{3(g)}$

16. For a 0.025 mol/L solution of $HCN_{(aq)}$, which condition is **true**?

• **A.** $[HCN_{(aq)}] > [H_3O^+_{(aq)}]$
B. $[OH^-_{(aq)}] > [H_3O^+_{(aq)}]$
C. $[CN^-_{(aq)}] > [H_3O^+_{(aq)}]$
D. $[HCN_{(aq)}] > [CN^-_{(aq)}]$

Question MC14 involves chemical concepts/knowledge unique to the new program of studies from Unit 3 Concept 1: "stating the criteria that apply to a system at equilibrium; e.g., closed system, constancy of properties, evidence of reversibility, equal rates of forward and reverse reaction." The expectation for this question is that students at acceptable standard will be successful. The difficulty of this item is 68.1%.

Question MC15 involves chemical concepts/knowledge unique to the new program of studies from Unit 3 Concept 1: "predicting whether or not reactants or products are favoured in a reversible reaction, on the basis of the magnitude of the equilibrium constant." The expectation for this question is that students at acceptable standard will be successful. It is not expected that students undertake to solve for the actual value of the equilibrium concentrations, although that approach to solving the question is mathematically challenging and valid. The difficulty of this item is 41.9%.

Question MC16 involves chemical concepts/knowledge unique to the new program of studies from Unit 3 Concept 1: "predicting whether or not reactants or products are favoured in a reversible reaction, on the basis of the magnitude of the equilibrium constant." The expectation for this question is that students at the acceptable standard will be successful. It is not expected that students undertake to solve for the actual value of the equilibrium concentrations, although that approach to solving the question is mathematically challenging and valid. The difficulty of this item is 40.3%.

The next item in this test is a numerical response question. Note that the question is numbered 1, in inverse print, even though this is the seventeenth question on the test.

Students should expect question formats to vary throughout the entire test. This question involves several chemical concepts/knowledge from the new program of studies. Specifically, Unit 3 Concept 3: “identifying conjugate pairs of Brønsted-Lowry acids and bases in chemical reaction equations” and Unit 3 Concept 1: “predicting whether or not reactants or products are favoured in a reversible reaction, on the basis of the magnitude of the equilibrium constant.” The expectation for this question is that students at the standard of excellence will be successful since this question requires students to integrate their knowledge. The difficulty of this item is 22.2%.

This item is also a numerical response question. Note that the question is numbered 2, in inverse print, even though it is the eighteenth question on the test. This question does not involve chemical concepts/knowledge unique to the new program of studies and addresses Unit 3 Concept 3: “defining and describing indicators and explaining their colour changes in terms of equilibrium shifts” and the skill “using indicators to determine the approximate pH of an acid or base solution.” The expectation for this question is that students at the acceptable standard will be successful. The difficulty for this item is 78.3%.

The nineteenth question is a multiple-choice question and is numbered 17 since it is the seventeenth multiple-choice question. It involves chemical concepts/knowledge unique to the new program of studies from Unit 3 Concept 2: “performing calculations to determine any of pH, pOH, $[H_3O^+{}_{(aq)}]$, $[OH^-{}_{(aq)}]$, K_a, or K_b from the masses of solute, volumes, and concentrations of solutions.” The expectation for this question is that students at the standard of excellence will be successful. The difficulty for this item is 22.7%.

Numerical Response

1. Use the equation:

$$\underset{(1)}{H_2PO_4^-{}_{(aq)}} + \underset{(2)}{HCO_3^-{}_{(aq)}} \rightleftharpoons \underset{(3)}{H_2CO_3{}_{(aq)}} + \underset{(4)}{HPO_4^{2-}{}_{(aq)}}$$

In the reaction that is favoured, the numbers that correspond to the acid, conjugate base, base, conjugate acid, respectively, are ______, ______, ______, and ______.

(Answer — 3241)

2. The following data were collected when four different solutions were tested with different indicators.

Solution	Indicator	Colour
1	indigo carmine	yellow
2	methyl red	orange
3	thymol blue	green
4	orange IV	red

Using this data, the four solutions arranged in order of decreasing pH are ______________.

(Answer — 1324)

17. A 0.0250 mol/L sample of a monoprotic acid is tested with a pH meter and determined to have a pH = 2.75. The calculated K_a for this acid is

- • **A.** 1.36×10^{-4}
- **B.** 1.26×10^{-4}
- **C.** 3.16×10^{-6}
- **D.** 7.35×10^{3}

18. If aqueous solutions of $NaHCO_{3(aq)}$, $NaHSO_{4(aq)}$, $NaHS_{(aq)}$, and $NaHSO_{3(aq)}$ were mixed together, the most probable Brønsted-Lowry acid base reaction would be

• **A.** $HSO_4{}^-{}_{(aq)} + HS^-{}_{(aq)} \rightleftharpoons H_2S_{(aq)} + SO_4{}^{2-}{}_{(aq)}$

B. $HCO_3{}^-{}_{(aq)} + HSO_3{}^-{}_{(aq)} \rightleftharpoons H_2CO_{3(aq)} + SO_3{}^{2-}{}_{(aq)}$

C. $HSO_4{}^-{}_{(aq)} + HSO_3{}^-{}_{(aq)} \rightleftharpoons H_2SO_{3(aq)} + SO_4{}^{2-}{}_{(aq)}$

D. $HCO_3{}^-{}_{(aq)} + HS^-{}_{(aq)} \rightleftharpoons H_2S_{(aq)} + CO_3{}^{2-}{}_{(aq)}$

19. Which of the following would **not** be a buffer system?

A. A weak acid and a salt of its conjugate base

• **B.** A weak acid and a strong acid

C. A weak base and its conjugate acid

D. A weak base and a weak acid

20. An acetic acid-sodium acetate buffer solution is prepared. When small amounts of $HCl_{(aq)}$ are added, the solution is able to maintain a near constant pH because

• **A.** the acetate ion in the buffer will react with almost all of the $H_3O^+{}_{(aq)}$ from the $HCl_{(aq)}$

B. $HCl_{(aq)}$ is a weak acid and will not interfere with the pH of the buffer

C. the $H_3O^+{}_{(aq)}$ from the $HCl_{(aq)}$ will react with the acetic acid molecules causing no change in pH

D. the $OH^-{}_{(aq)}$ in the aqueous buffer will neutralize the $H_3O^+{}_{(aq)}$ from the $HCl_{(aq)}$

Question MC18 does not involve chemical concepts/knowledge unique to the new program of studies and addresses Unit 3 Concept 3; “writing and interpreting chemical reaction equations illustrating the Brønsted-Lowry definition of acids and bases and neutralization” and the skill “predicting the most likely acid-base reaction, using tables of relative acid-base strength.” The expectation for this question is that students at acceptable standard will be successful. The difficulty for this item is 73.0%.

This question does involve chemical concepts/knowledge unique to the new program of studies and addresses Unit 3 Concept 3: “explaining how buffers maintain a relatively constant pH when small amounts of acid, base, or solvent are added to an aqueous system.” The expectation for this question is that students at acceptable standard will be successful. The difficulty for this item is 72.5%.

This question is another example of Unit 3 Concept 3: “explaining how buffers maintain a relatively constant pH when small amounts of acid, base, or solvent are added to an aqueous system.” The expectation for this question is that students at the acceptable level will be successful. The difficulty for this item is 55.5%.

The shaded text indicates that there is another series of questions that are based upon the scenario/context/STS introduction. In this case, there is a series of questions based upon the chemistry involved an industrial lab analysis.

This question does not involve chemical concepts/knowledge unique to the new program of studies and addresses Unit 3 Concept 3: "performing calculations related to quantitative reactions between acids and bases, including excess reagents in strong acid-strong base combinations" and the skill: "performing a titration experiment and related calculations to determine the concentration of an acid or base solution." The expectation for this question is that students at acceptable standard will be successful. The difficulty for this item is 53.5%.

Question MC22 does not involve chemical concepts/knowledge unique to the new program of studies and addresses Unit 3 Concept 3: "differentiating between indicator end point and equivalence point." The expectation for this question is that students at acceptable standard will be successful . The difficulty for this item is 37.5%.

Question MC23 does not involve chemical concepts/knowledge unique to the new program of studies and addresses Unit 3 Concept 3: "performing calculations related to quantitative reactions between acids and bases, including excess reagents in strong acid-strong base combinations" and the skill: "using a pH meter and laboratory glassware related to titrations." The expectation for this question is that students at standard of excellence will be successful. The difficulty for this item is 27.7%.

In the analysis of a chemical spill of hydrochloric acid, Phill, an environmental chemist with Hoky Services, titrated a 10.0 mL sample of $HCl_{(aq)}$ to a green bromocresol green end-point with 0.023 mol/L $NaOH_{(aq)}$. The volume required for four successive titrations was 10.4 mL, 16.5 mL, 16.6 mL, and 16.4 mL.

21. The value for the concentration of the sample is

A. 0.15 mol/L
• **B.** 0.038 mol/L
C. 0.034 mol/L
D. 0.014 mol/L

22. One should conclude that in the titration

A. the equivalence point had been reached
B. the indicator endpoint occurred just after the equivalence point
C. the actual concentration of Phill's sample is much lower than the experimental value
• **D.** an inappropriate end-point was selected for the titration

23. If Phill had used a pH meter instead of an indicator and took pH readings for each consecutive 1.0 mL addition of $NaOH_{(aq)}$ until excess base was present in the flask. The next step Phill must perform to find the concentration of the acid is to

A. calculate the number of moles of base
• **B.** draw the titration curve
C. calculate the number of moles of acid
D. find the equivalence point

Sample Test Items

This shaded text indicates that there is a series of questions to follow, which is based upon the scenario/context/STS introduction. In this case, there is a series of soft-linked questions.

Numerical-response question 1 can only be answered by interpreting the accompanying diagram. The difficulty for this item is 78.7%.

Numerical-response question 2 requires the student to utilize information contained in the context and the recorded answer to numerical-response question 1 to arrive at a correct response. If the student answered the first question incorrectly, but used this incorrect information correctly, the student would receive full marks for this question. The total difficulty for this item is 69.5%, with 62.6% of the students correctly answering the first question and 6.9% of the students answering the question appropriately but not correctly answering the first question.

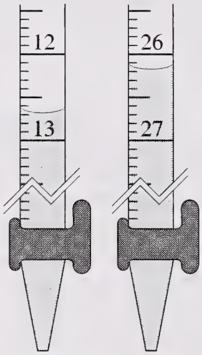
Numerical-response question 3 requires the student to use the value recorded in numerical-response question 2 to arrive at a correct response. If the student answered that question incorrectly, but used this incorrect information correctly, the student would receive full marks for this question. The total difficulty for this item is 43.3%, with 36.1% of the students correctly answering numerical-response question 2 correctly and 7.2% of the students answering the question appropriately but not correctly answering the preceding question

Multiple-choice question 1 ends this group of questions and does not require any values obtained in numerical-response questions 1 to 3. The difficulty of this question is 22.4%.

The effluent of a pulp and paper mill can be tested to determine the levels of waste caustic soda, $NaOH_{(aq)}$. Titration is an important means of quantitative analysis. A 250 mL sample of water downstream from the mill is titrated with 0.200 mol/L $HCl_{(aq)}$.

Numerical Response

1. Based on the diagram, the volume of $HCl_{(aq)}$ used in the titration is __________ mL.
(Record your answer to three digits on the answer sheet.)



Numerical Response

Use your answer from Numerical Response 1 to answer Numerical Response 2.

2. The concentration of sodium hydroxide, $NaOH_{(aq)}$, in the sample is __________ mmol/L.
(Record your answer to three digits on the answer sheet.)

Numerical Response

Use your answer from Numerical Response 2 to answer Numerical Response 3.

3. The pH of the sample would be __________.
(Record your answer to three digits on the answer sheet.)

1. A suitable choice of indicator combined with the correct colour change of indicator to identify the equivalence point in this reaction is

A. litmus, red to blue
B. phenol red, red to orange
C. methyl orange, yellow to pink
D. bromothymol blue, yellow to green

Sample Test Items

These items have been selected to illustrate clarifications and new emphases since the 1997 examinations.

Students should be able to perform questions like this using K_a, hence they should also be able to solve this question. The major problem is the application of the "approximation" in situations where it is clearly inappropriate.

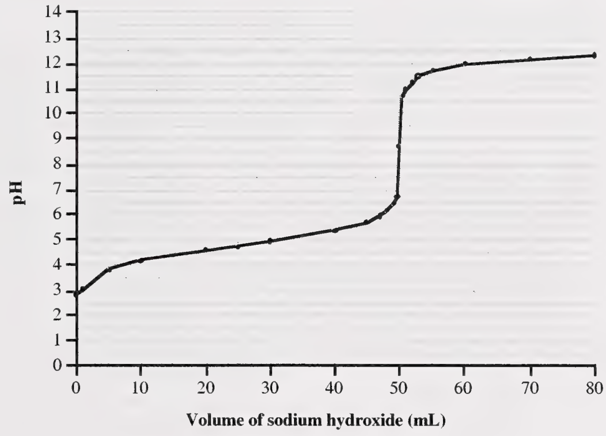
1. If a 0.150 mol/L solution of hydrazine, $N_2H_{4(aq)}$, has a pH = 10.70, what is the value of K_b for $N_2H_{4(aq)} + H_2O_{(l)} \rightleftharpoons N_2H_5{}^+{}_{(aq)} + OH^-{}_{(aq)}$?

•A. 1.7×10^{-6} mol/L
B. 2.0×10^{-11} mol/L
C. 5.0×10^{-4} mol/L
D. 2.5×10^{-7} mol/L

Students should be able to distinguish between the terms "end point" and "equivalence point."

Use the following information to answer the next question.

A dilute acid solution was titrated with 0.10 mol/L $NaOH_{(aq)}$. The following titration curve was obtained.



2. The same acid was titrated with 0.10 mol/L $NaOH_{(aq)}$ using indigo carmine indicator. A student correctly predicted that the volume of $NaOH_{(aq)}$ required for this titration would be

A. less because the equivalence-point occurs after the visual endpoint

B. greater because the equivalence-point occurs after the visual endpoint

C. less because the end-point occurs after the equivalence point

•D. greater because the end-point occurs after the equivalence point

If students use an approximation, they will arrive at the incorrect answer D rather than the correct value C.

3. The trace amounts of sulphur dioxide produced in the firing of brick, if released into the air, can react with water in the atmosphere to produce sulphurous acid. The concentration of sulphurous acid required to produce a solution of pH 5.62 is

A. 2.3×10^{9} mol/L
B. 5.4×10^{3} mol/L
•C. 2.4×10^{-6} mol/L
D. 4.4×10^{-10} mol/L

Students should be able to identify the STS perspectives.

4. Which statement is **not** correctly labelled?

A. Altering the operating temperature of a furnace is a method of controlling the amounts of toxic emissions. (technological)

•B. Knowledge of the role of oxygen molecules in combustion reactions was essential to early smelting operations. (technological)

C. Ernest Solvay's soda ash production process used relatively inexpensive raw materials easily accessible from limestone cliffs and salt water. (economic)

D. A government decision to ignore high levels of pollution downstream from a city had little public support. (environmental)

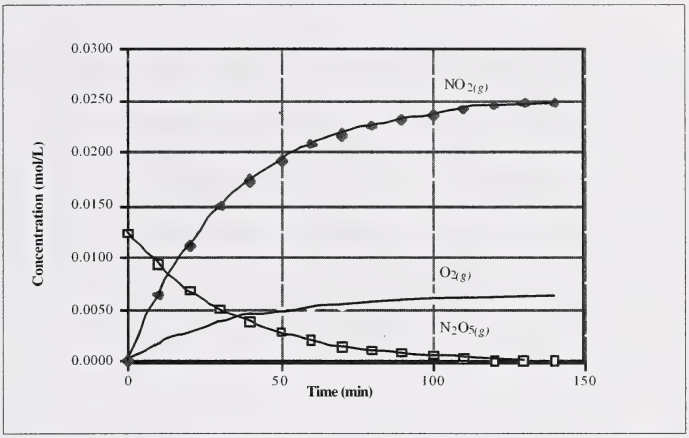
This should be a straightforward calculation that all students should be able to perform successfully. Lack of success on questions like this can be traced back to the use of approximations to avoid solving quadratic expressions.

5. The equilibrium $4H_{2(g)} + N_2O_{4(g)} \rightleftharpoons N_{2(g)} + 4H_2O_{(g)}$ was investigated. Initially, 1.60 mol of $H_{2(g)}$ and 1.00 mol of $N_2O_{4(g)}$ were injected into a 1.00 L vessel. When equilibrium was established, the concentration of $H_{2(g)}$ was 1.20 mol/L. The equilibrium constant for the reaction was

•A. 1.37×10^{-3}
B. 7.29×10^{2}
C. 3.70×10^{-2}
D. 2.50×10^{-2}

Students should recognize that this is not an equilibrium because the concentration of the reactant(s) is zero.

Use the following information to answer the next question.



6. Based on this graph, a logical conclusion is that the decomposition of $N_2O_{5(g)}$ into $O_{2(g)}$ and $NO_{2(g)}$ is

A. an equilibrium reaction, with the products favoured

B. en equilibrium reaction, with the reactants favoured

•C. a quantitative reaction

D. a non-spontaneous reaction

The following questions have been selected to illustrate some common student misconceptions.

Students are required to recognize that a buffer system is composed of a conjugate weak acid and a weak base pair that maintain a nearly constant pH when diluted or when a strong acid or base is added.

1. A buffer solution could be prepared by mixing equal concentrations of

A. $HCl_{(aq)}$ and $NaCl_{(aq)}$
B. $HCl_{(aq)}$ and $NaOH_{(aq)}$
•C. $H_2CO_{3(aq)}$ and $NaHCO_{3(aq)}$
D. $NaHCO_{3(aq)}$ and $NaCl_{(aq)}$

Students are expected to calculate the pH of a buffer solution given the concentrations of the conjugate acid–base pair and/or utilizing K_a.

Note: Although all three questions relate to buffer systems, the numerical-response questions could be asked about any system at equilibrium.

Numerical Response

1. A buffer solution prepared by mixing equal volumes of 0.68 mol/L $CH_3COOH_{(aq)}$ and 0.51 mol/L $NaCH_3COO_{(aq)}$ has a pH of ________.
(Record your answer to three digits on the answer sheet.)

Answer: 4.62 or 4.61

Numerical Response

2. A buffered solution contains 0.50 mol/L $NaHS_{(aq)}$ and 0.50 mol/L $H_2S_{(aq)}$ at equilibrium. The buffer equilibrium can be represented by the equation

$$H_2S_{(aq)} + H_2O_{(l)} \rightleftharpoons HS^-_{(aq)} + H_3O^+_{(aq)} \quad K_a = 1.1 \times 10^{-7}$$

The pH of this solution is ________.
(Record your answer to three digits on the answer sheet.)

Answer: 6.96

Note: Numerical-response questions specify that answers are recorded to three digits (**not** three significant digits); for example, 0.01 has three digits.